G-2 Injection Kicker Step Response Measurement

By Howie Pfeffer, George Krafcyzk, Dennis Barak and Chris Jensen
E/E Support Department / Accelerator Division
Measurement Completed On 10 January 2018

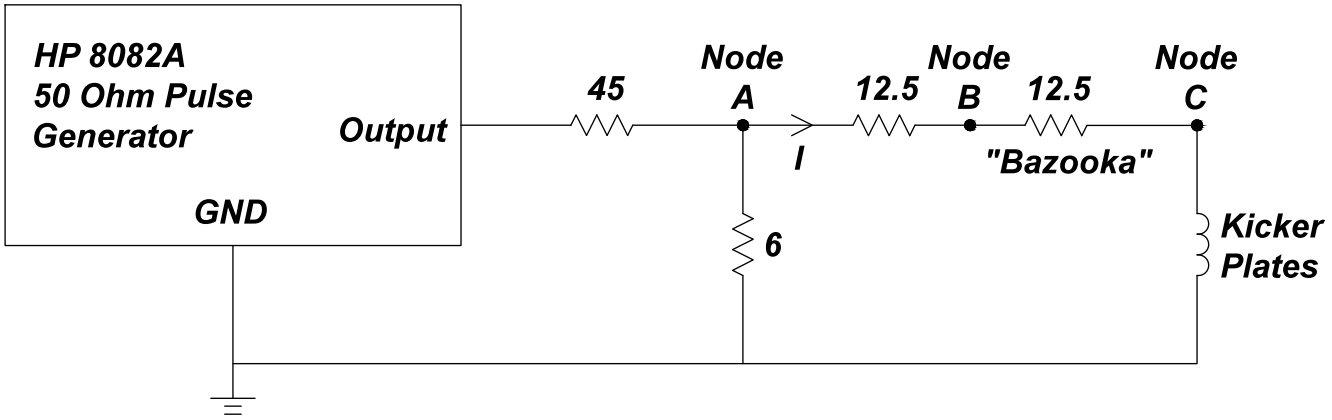
1. Introduction

Given the uncertainty in the expected rise time of the G-2 injection kickers, we made a measurement of the rise time using a fast, low impedance pulse generator, a 12.5 ohm resistor to mimic the impedance of the Blumlein and coax cables, the 12.5 ohm Bazooka that is the terminating resistor for the Blumlein, and the kicker structure in kicker #3.

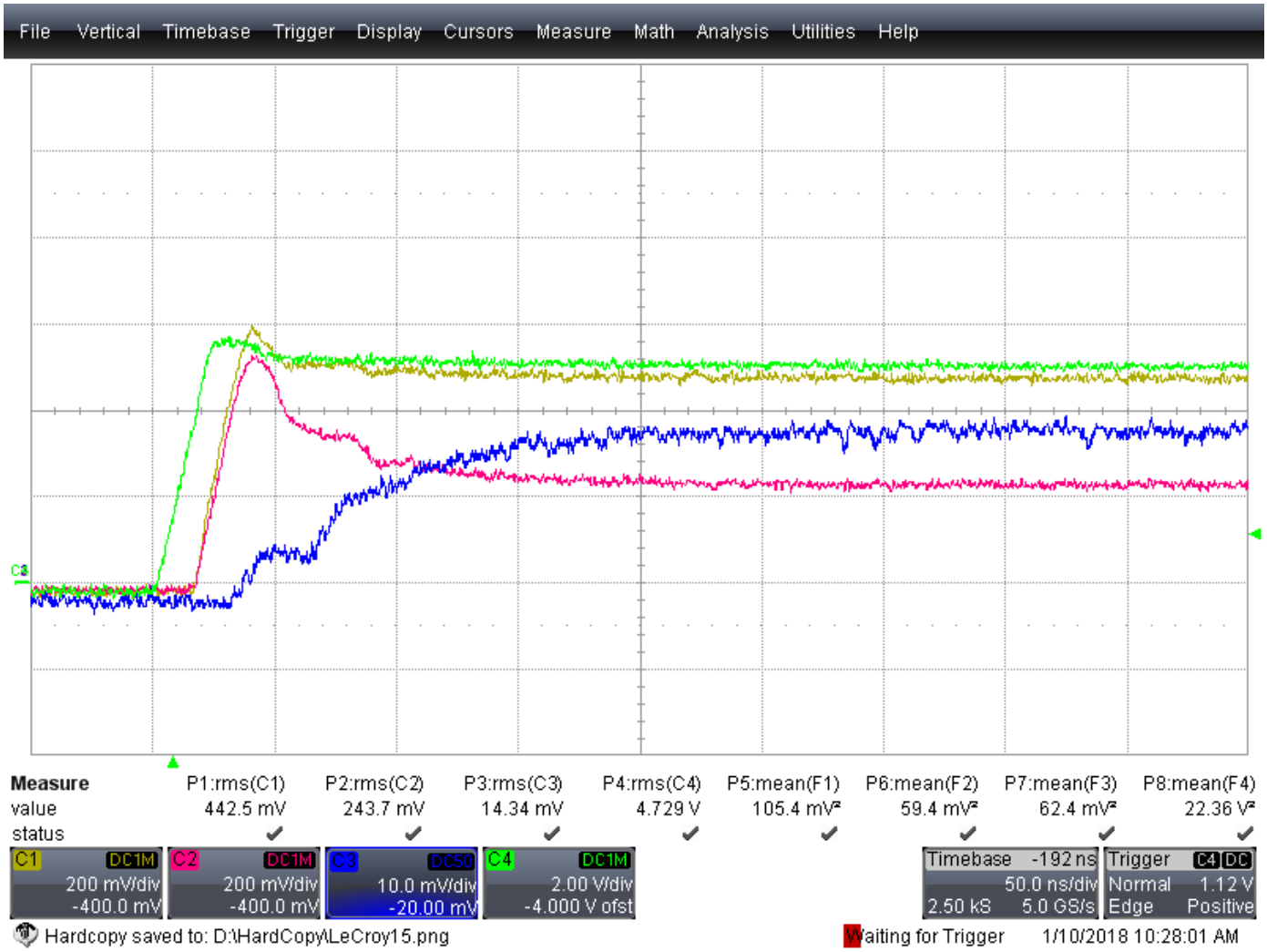
The following instruments were used to complete this measurement:

- HP 8082A Pulse Generator
- In-house 10 Ohm Pulse Generator
- LeCroy 104MXi-A oscilloscope
- Tektronix TCPA300 Amplifier, AC/DC Probe
- Tektronix TCP305A Current Probe

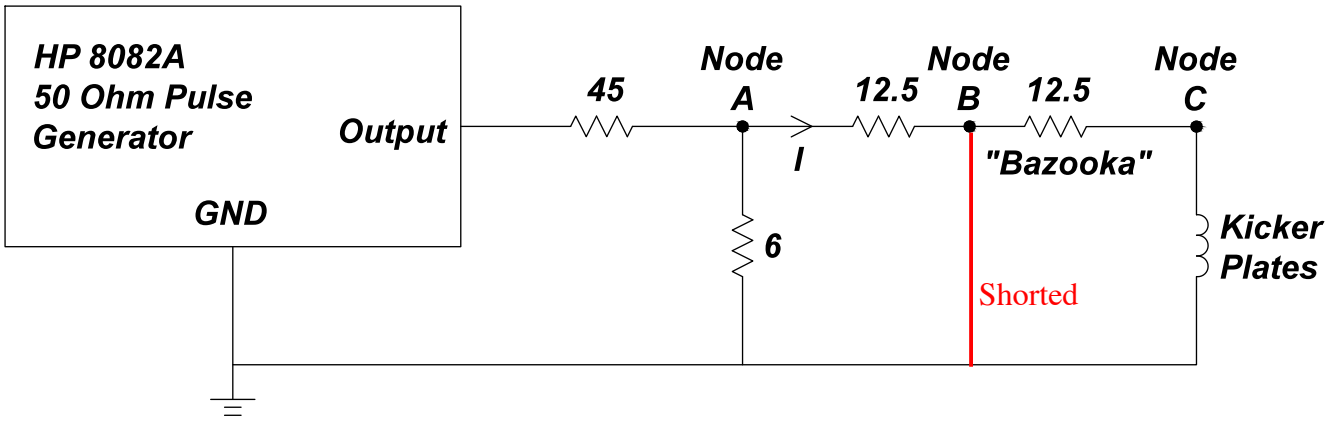
2. 50 Ohm Pulse Generator



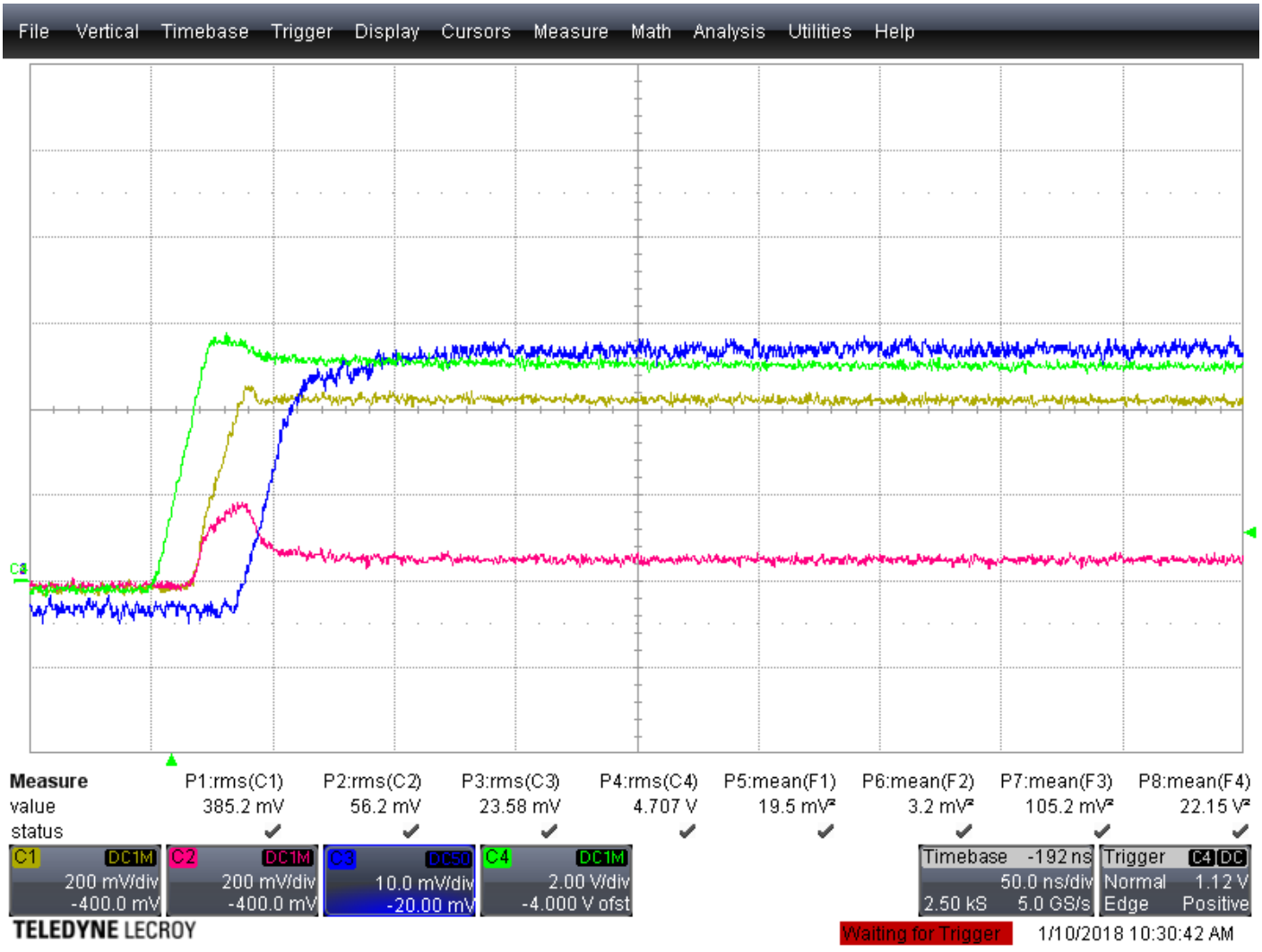
Vol. Div. Amplitude	Ch 1	Ch 2	Ch 3	Ch 4
500 mV	Node A	Node B	Load Current I (1 A/V)	Pulse Gen Output

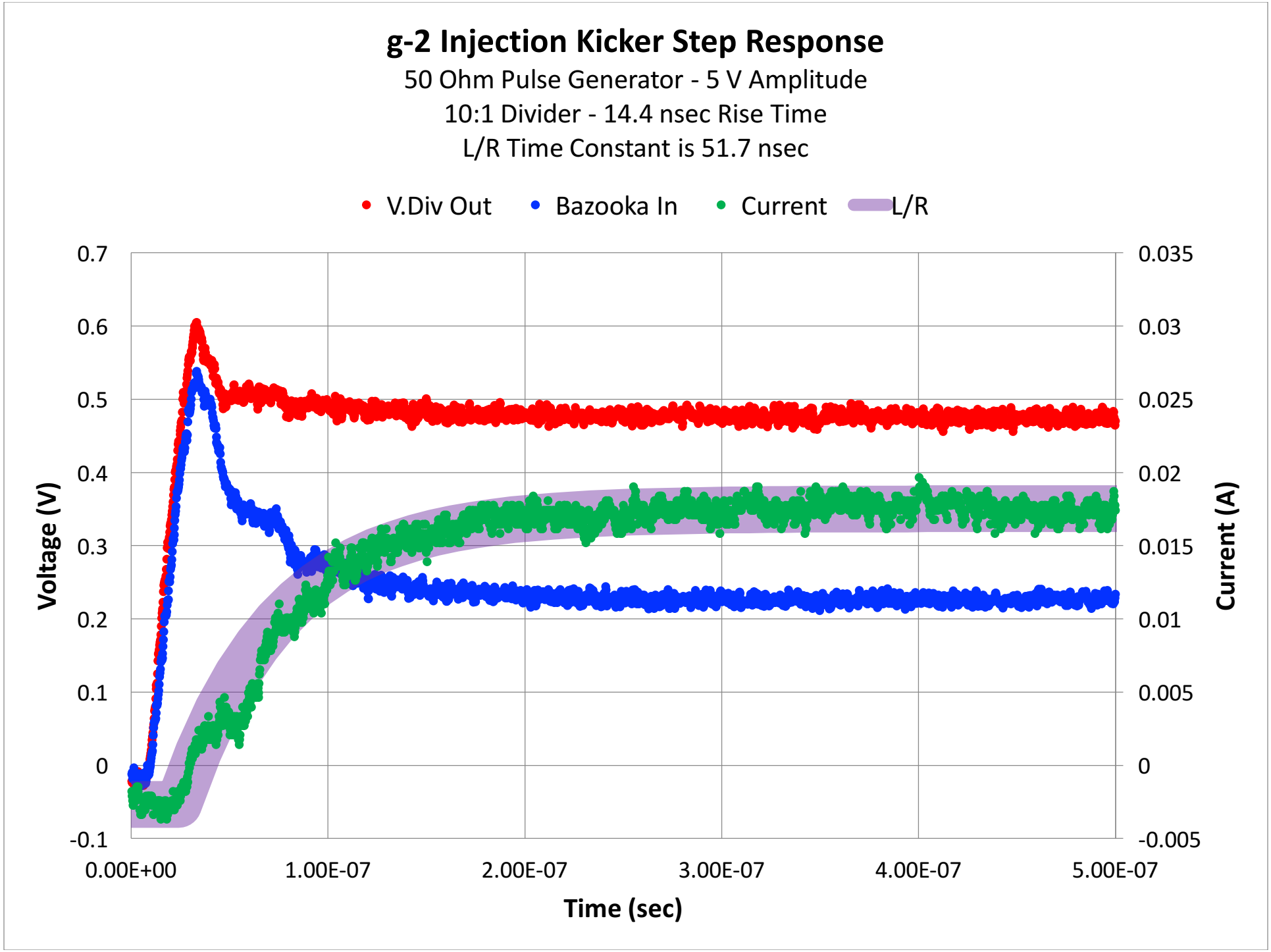


Then with Node B shorted to ground we see that our current probe has a very fast response.

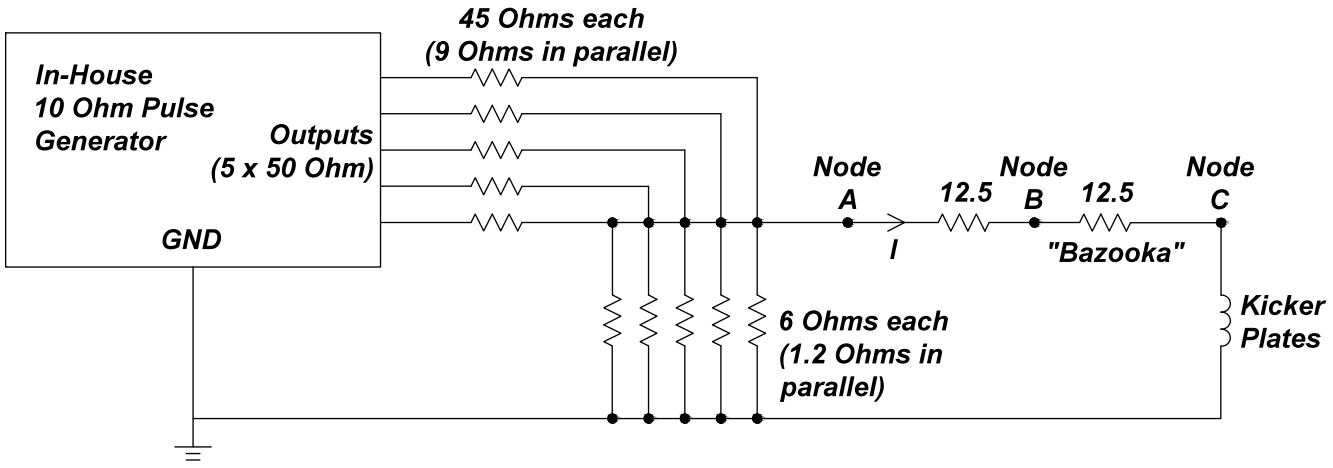


Vol. Div. Amplitude	Ch 1	Ch 2	Ch 3	Ch 4
500 mV	Node A	Node B	Load Current I (1 A/V)	Pulse Gen Output

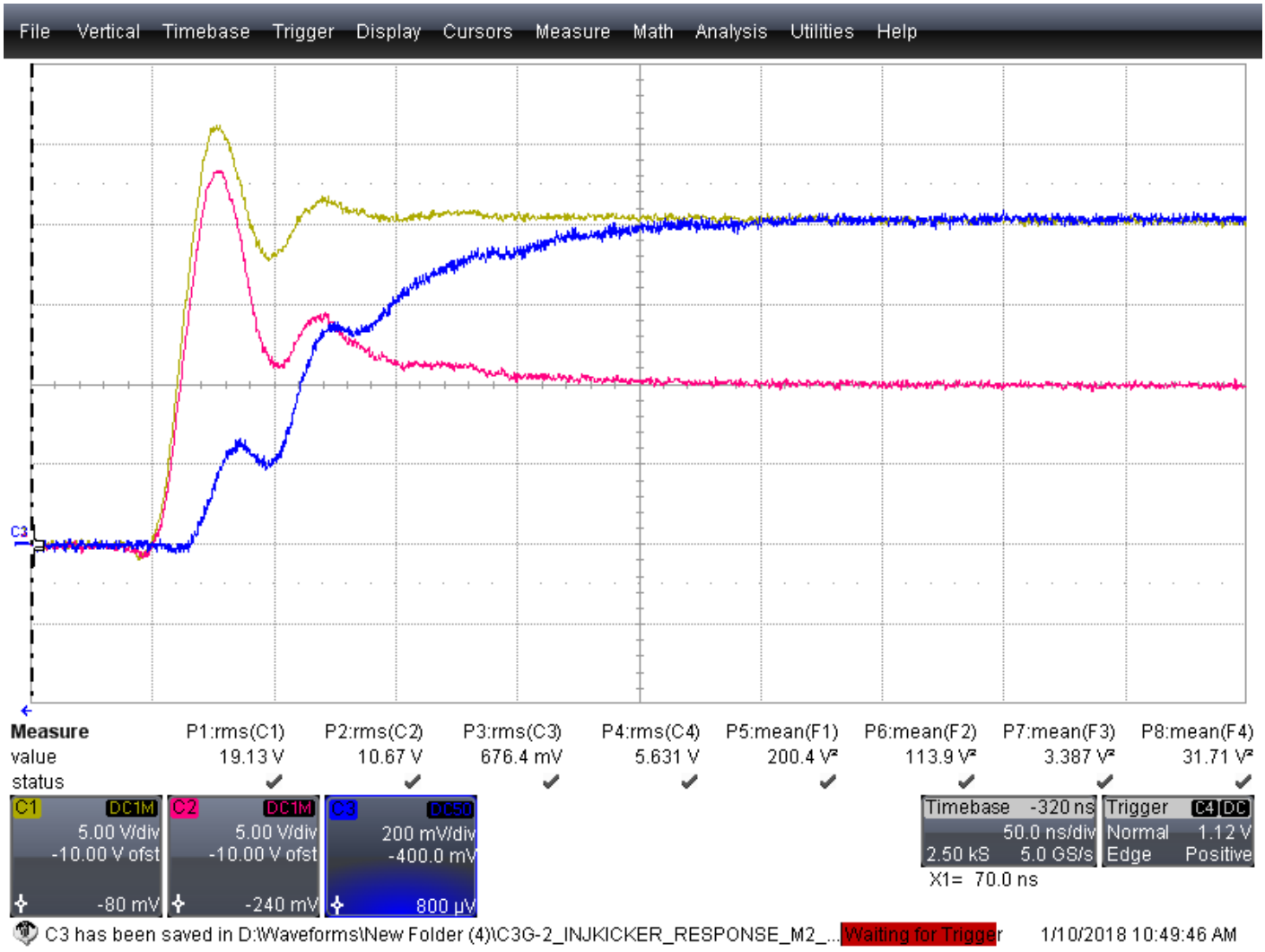



g-2 Injection Kicker Step Response
50 Ohm Pulse Generator - 5 V Amplitude
10:1 Divider - 14.4 nsec Rise Time
L/R Time Constant is 51.7 nsec
V.Div Out
Bazooka In
Current
L/R
Voltage (V)
Current (A)
Time (sec)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0.00E+00
1.00E-07
2.00E-07
3.00E-07
4.00E-07
5.00E-07

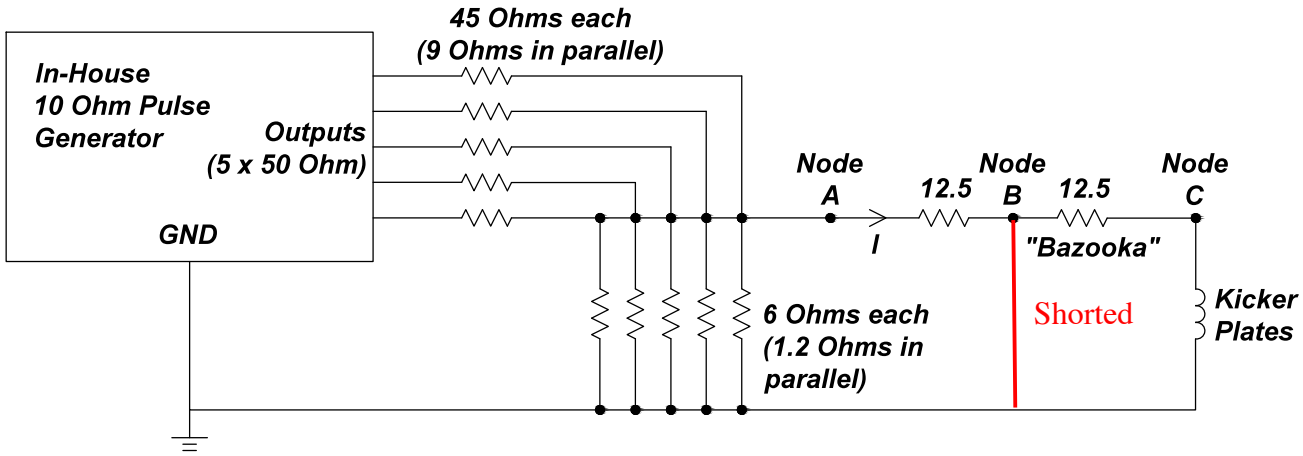
3. 10 Ohm Pulse Generator



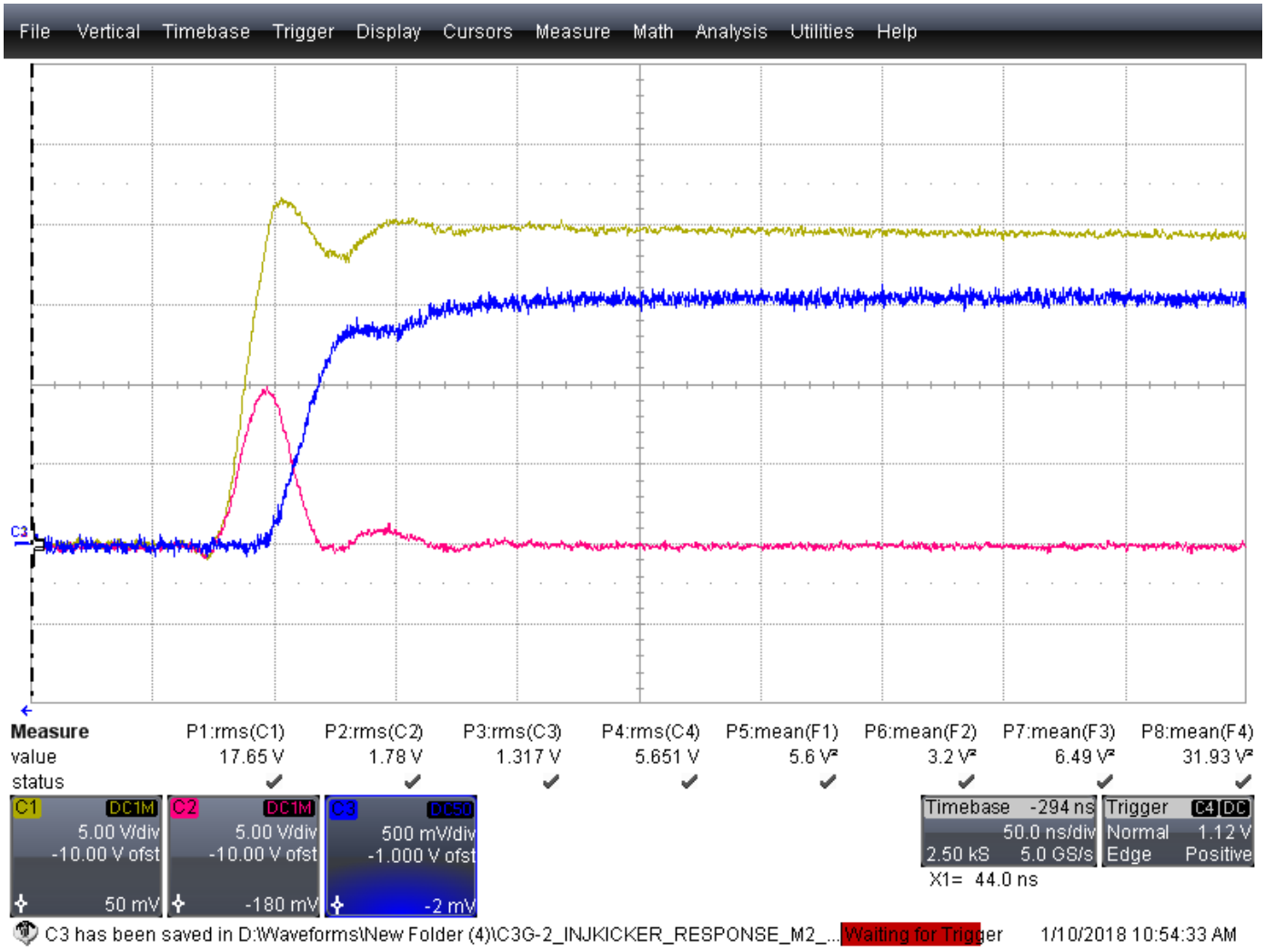
Vol. Div. Amplitude	Ch 1	Ch 2	Ch 3
20 V	Node A	Node B	Load Current I (1 A/V)

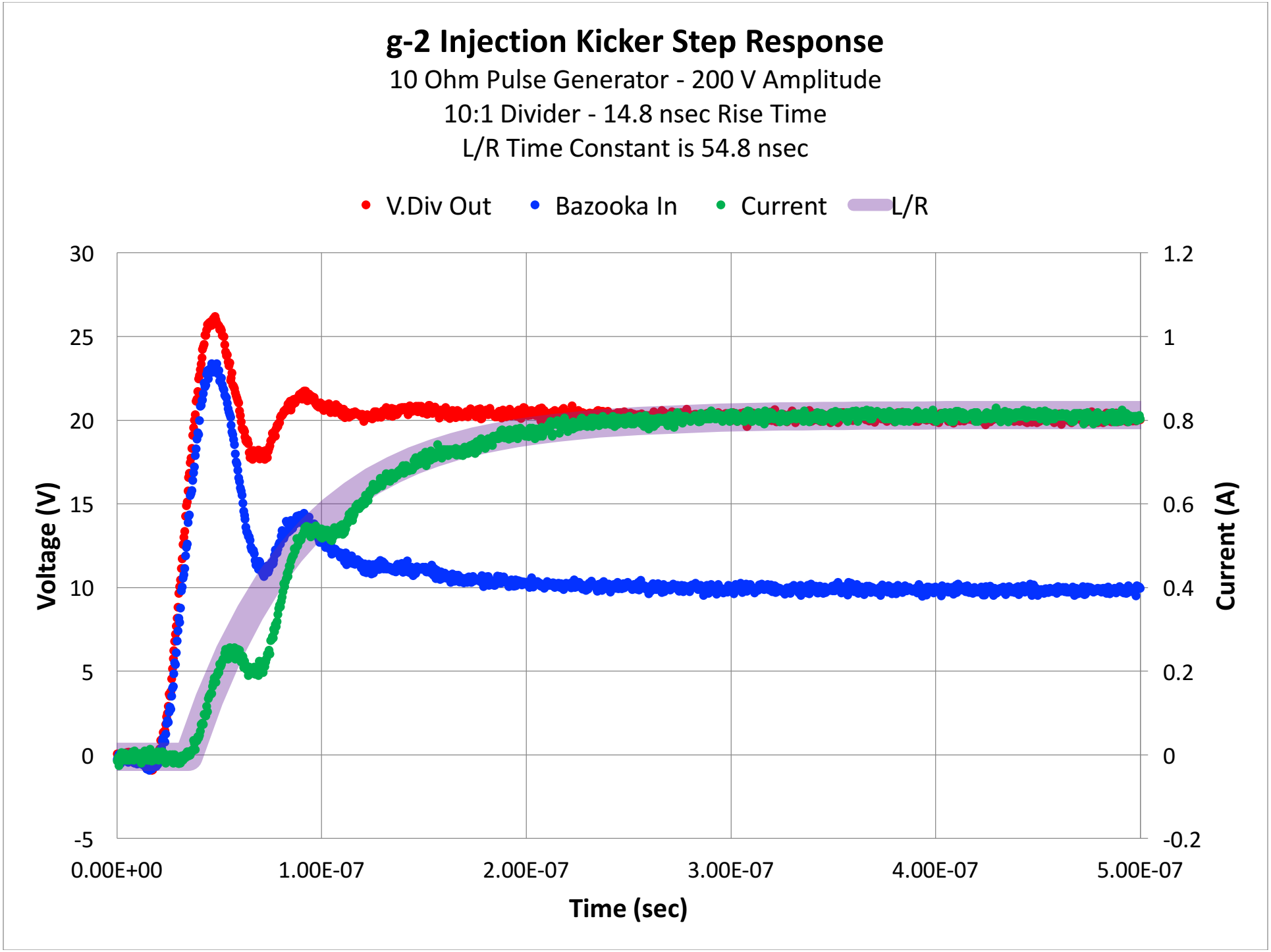


Then with Node B shorted to ground we see that our current probe has a very fast response.

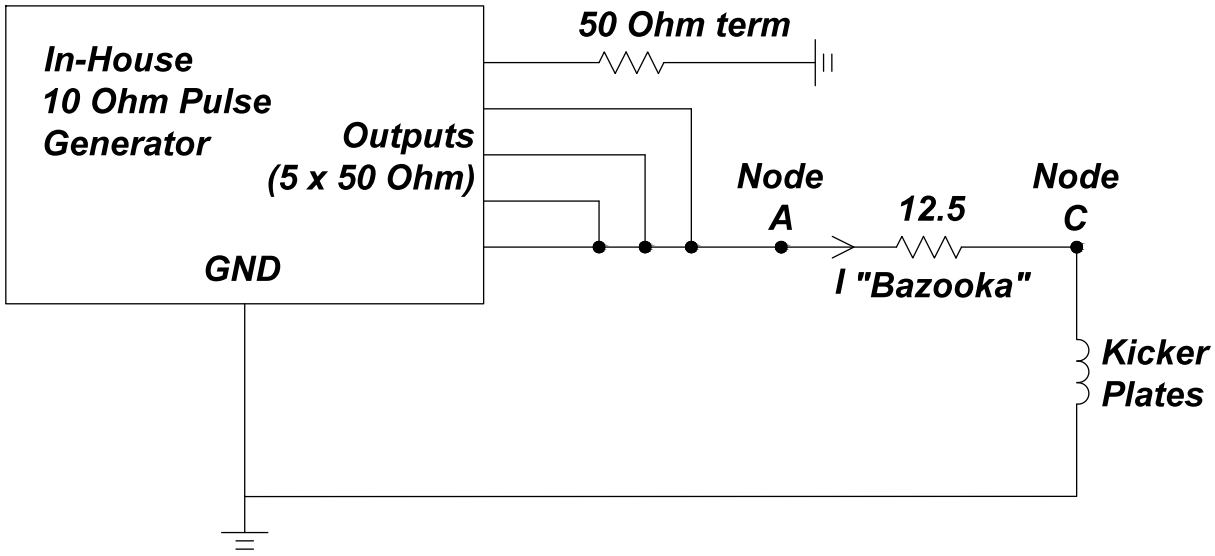


Vol. Div. Amplitude	Ch 1	Ch 2	Ch 3
20 V	Node A	Node B	Load Current I (1 A/V)

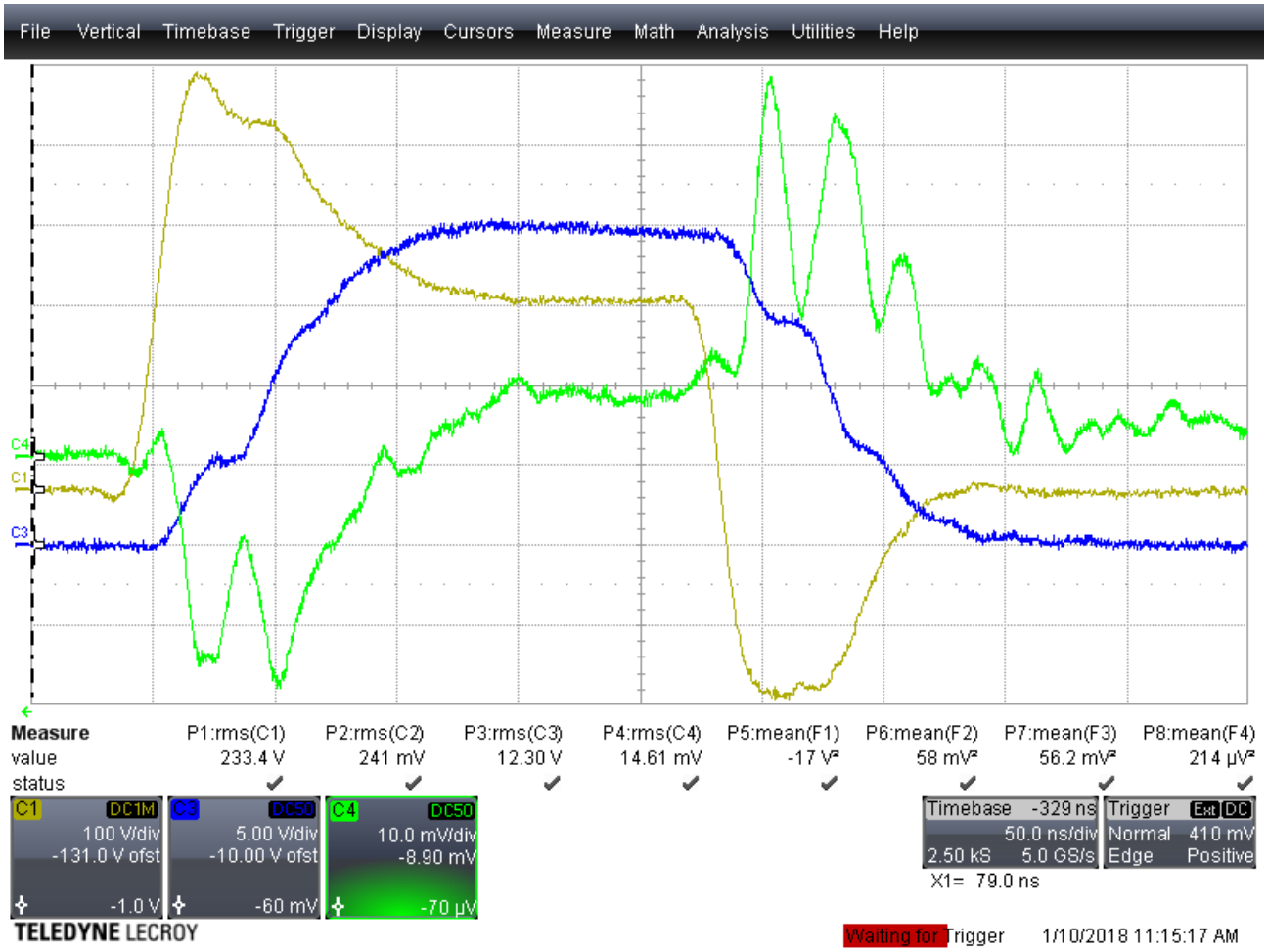



g-2 Injection Kicker Step Response
10 Ohm Pulse Generator - 200 V Amplitude
10:1 Divider - 14.8 nsec Rise Time
L/R Time Constant is 54.8 nsec
V.Div Out
Bazooka In
Current
L/R
Voltage (V)
Current (A)
Time (sec)
30
25
20
15
10
5
0
-5
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0.00E+00
1.00E-07
2.00E-07
3.00E-07
4.00E-07
5.00E-07

4. 12 Ohm Pulse Generator



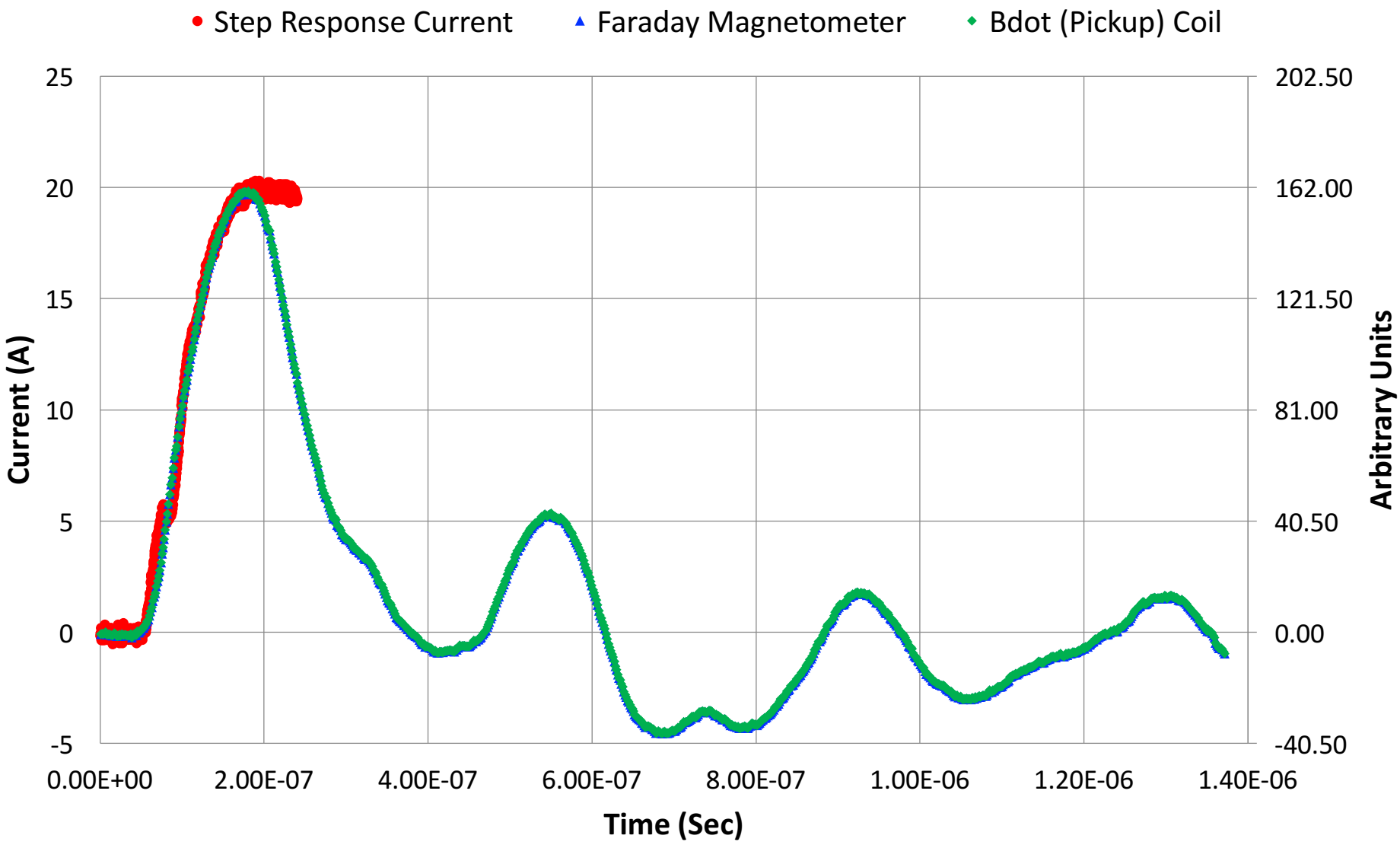
Pulse Amplitude	Load Current	Ch 1	Ch 3	Ch 4
240 V	20 A	Node A	Load Current I (1 A/V)	Bdot Probe



g-2 Injection Kicker Step Response vs. Actual Magnetic Field Measurements

Step Response Current From 240 V, 20 A Peak Pulse

Magnetic Field Measurements From Kicker Powered By Blumlein



5. Conclusions

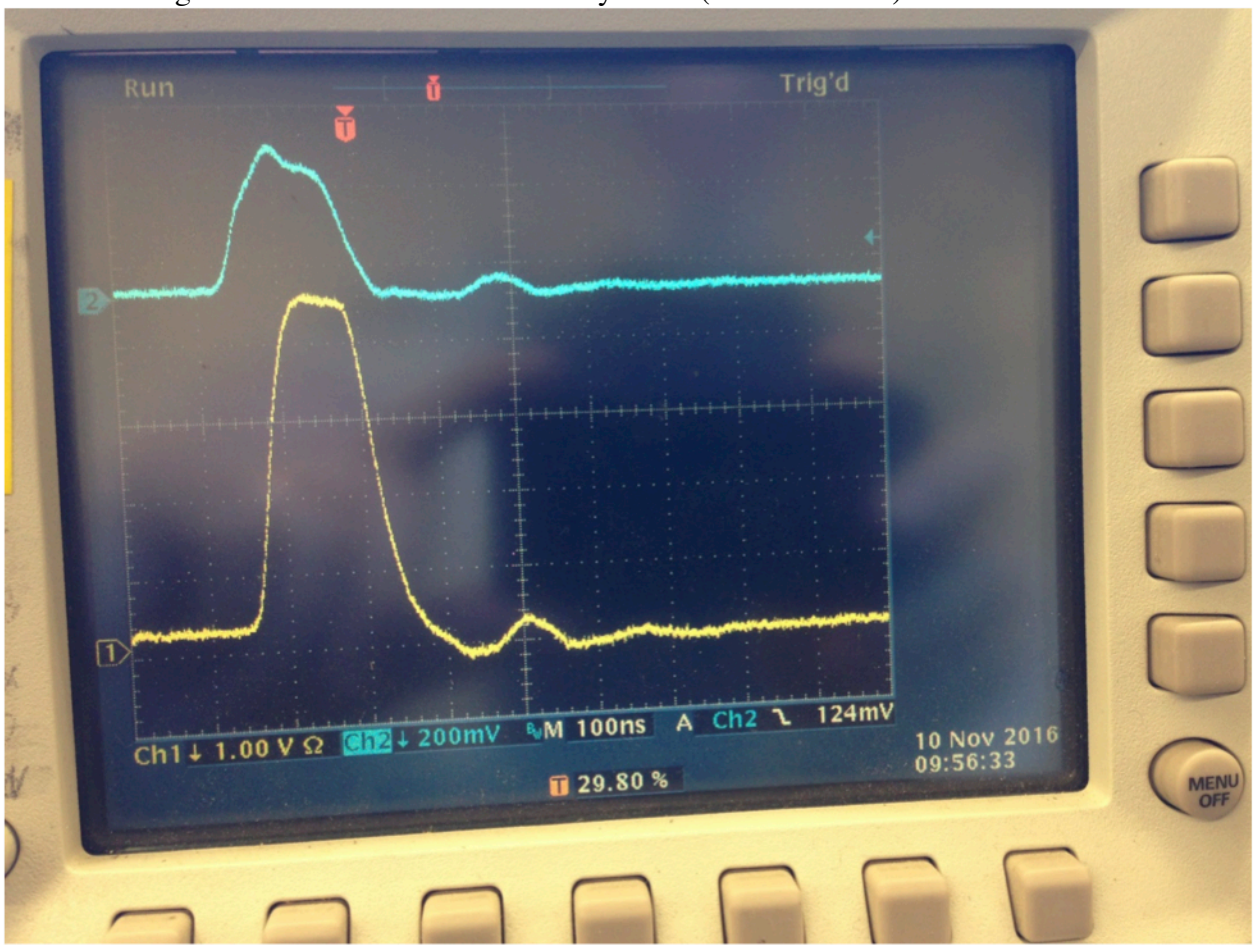
- The inductance of the kicker measured with an HP vector impedance analyzer is 1.1 μH.
- The g-2 injection kicker looks like an RL circuit with an L/R time constant of ~ 54 ns.
- The effective inductance of the kicker and series Bazooka = (54 ns)(25ohm) = 1.35 μH.
    - It may actually be higher than this since the resistance in the loop was 25 Ohms + 1 Ohm or 5 Ohms depending on the pulse generator being used.
- The measured current is still rising when the pulse would be terminated at 150 ns.
- The measured rise time is consistent with the rise time of the field measured with the faraday magnetometer on each of the kickers at Fermilab.
- The rise time is consistent with circuit models we have made using both SPICE and EMTP.
- Pulse measurements completed on the prototype kicker at Cornell are shown in the Appendix.
- The previous operating current measurement is shown in ISBN 978-3-95450-182-3.

6. Appendix

Kicker Magnetic Field Magnetic Field Measurements and Shorted Kicker Current Measurements

These images were taken from the g-2 Kicker page at https://www.classe.cornell.edu/~dlr/g-2/kicker/kicker.html

Current through Bazooka resistor with "dummy" load (shorted kicker):



Current through prototype kicker with 50 kV pulse:

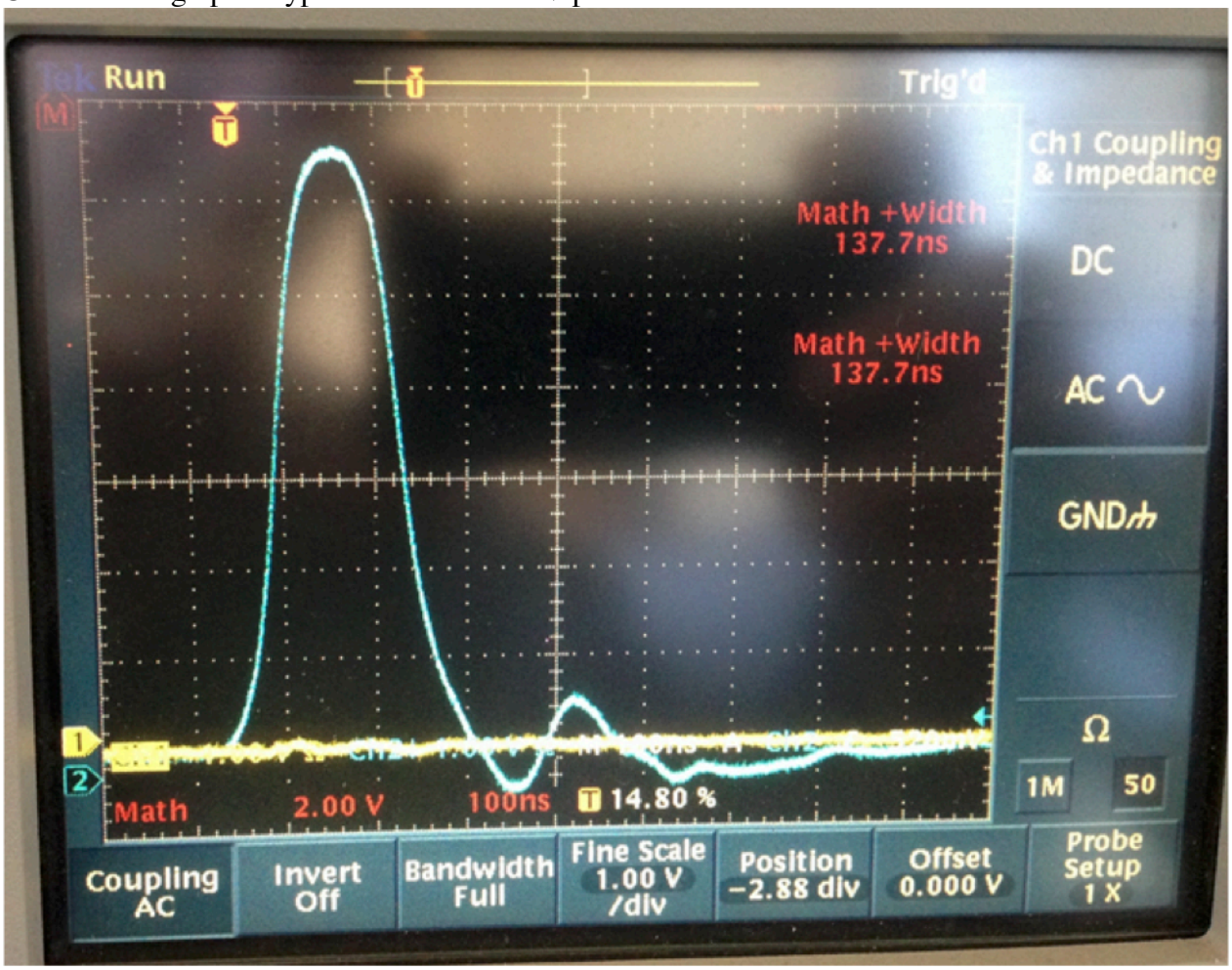


Figure from this note regarding the development of the Faraday Magnetometer for kicker magnetic field measurements:

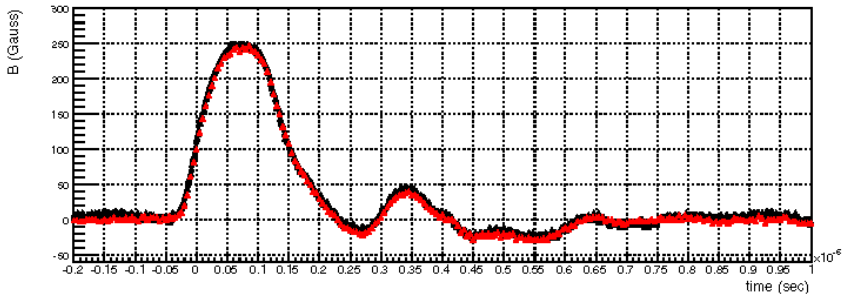


Figure 9: The protype kicker pulse measured by the simple FM (Version 2). Red and black plots are two repeated measurements. The vertical axis is converted into magnetic field unit based on the calibration.